LCA Case Studies

The Maintenance of Linoleum and PVC Floor Coverings in Sweden

The Significance of the Usage Phase in an LCA

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Abstract

Goal, Scope and Background. An extensive life cycle inventory of the maintenance of floor coverings has been carried out for the professional cleaning sector in Sweden. Different maintenance methods for linoleum and PVC were inventoried. The objective has been to develop a model for estimating the resource use in the Swedish professional floor cleaning and maintenance sector.
Several important actors involved in the Swedish professional cleaning sector participated in the inventory. An agreement could be reached for a limited number of methods and products. The result can be regarded as representative for the maintenance of linoleum and PVC in respect to professional maintenance in Sweden.

Methods, Results and Discussion. The maintenance was divided into two different types: periodical and frequent maintenance. It showed that 36 maintenance systems were relevant (each system is a combination of periodical and frequent maintenance) and that the expected impacts from maintenance could be found through an inventory of these 36 systems. The resource use for each system was inventoried and pertaining LCI data was collected. However, it showed that the resource use for the maintenance systems could not be quantified without estimating three so called 'application-specific context parameters', which were not depending on the maintenance system but related to the specific type of premises. The three parameters were: the frequency of the periodical maintenance (P); the frequency of the frequent maintenance (P), and; the estimated service life (L) of the floor covering. The prediction of a specific resource use for maintenance of a specific floor covering could thereby not be carried out without the knowledge of the three application-specific parameters. However, all collected data were supplied to a specifically developed calculation program, which made it possible to estimate the impact from the 36 maintenance systems for different choices of estimated service life and maintenance intervals for the periodical and frequent maintenance. Approximately 1300 different scenarios were provided, using different values for F, P and L, respectively, and compared in order to answer several questions of concern to the professional cleaning sector in Sweden.

Conclusions. Some of the most important conclusions generated from the scenarios were: The impacts from maintenance proved to be significant compared to the impacts from the floor. In several cases, wax-based systems turned out to be preferable to polish systems. However, the result is sensitive to the chosen cleaning method. When polish systems are chosen, the choice of floor covering may influence the usage phase in a significant way.

Recommendation and Outlook. A framework has been provided as a base for further development. Possibly, the data could be improved and supplied with data of other products and materials. Even other types of floor coverings may be considered. The focus has primarily been on energy use and emission of chemicals recorded as dry substance. It is desirable with a development of a method for quantitative assessment of the actual chemicals.

Keywords: Building products; floor coverings; life cycle assessment (LCA); linoleum; maintenance; material choice; PVC floor coverings; usage phase

1 Goal, Scope and Background

During recent years, environmental issues have become more important in the building and construction sector. Life cycle assessment has been recognised as a valuable tool to compare and support improvements of the environmental performance of building products. The method is primarily based on calculation and evaluation of quantitative parameters covering the whole life cycle of the analysed product. An analysis is often carried out on the product level, while in order to include the usage phase, information is required on expected service life, type of maintenance, interference with the surroundings, etc. The necessary information may depend on the context of the building product. One type of environmental loads that may occur in the usage phase is due to maintenance. Building products have a significant longer service life than most other product groups on which the LCA methodology has been applied. Accordingly, the usage phase could be expected to cause a significant contribution to the total impact over a building product's life cycle. Especially the maintenance of building products has been found in need of development regarding the LCA methodology (SETAC 2000).

To develop the application of LCA methodology on building products and maintenance, a major inventory of floor coverings has been carried out in Sweden (Paulsen 1999). The inventory has resulted in a framework comprising a calculation model, a simple calculation program and a comprehensive amount of data regarding professional maintenance of linoleum and PVC in Sweden. The most important findings from that study will be presented in this article.

The choice of floor coverings as the product group of consideration can be motivated from several viewpoints. A number of studies had already been carried out to compare different types of floor coverings, employing the LCA methodology (Gunther and Langowski1997, Jönsson 1995, Potting 1993). In all these studies, the maintenance was omitted. However, in these studies it is indicated that the maintenance may give rise to environmental loads that are significant compared to the production of floor coverings. One study (Gunther and Langowski 1997) shows that energy use for vacuum cleaning of textile floorings may be significant. Another study of floor coverings (Lundblad 1994) indicated that the difference in environmental loads from the maintenance could be significant depending on the type of floor coverings.

The framework, which has been developed together with the calculation program, has a number of features that have to be discussed from a scientific point of view. It is not a precise tool, and a lot of improvements can be done. The data material collected for the inventory only covers some products. In addition, the amounts of chemicals used (dosage) for the different cleaning and maintenance methods may vary between different cleaning companies. Several important actors from the industry have been involved in the collection process of data of products and methods, and a selection has been done to limit the project to a reasonable level. Furthermore, a problem has been to estimate the impacts from the chemical use. The amount of products used has been taken as an environmental indicator, as far as a rough estimation is concerned.

Nevertheless, a framework has been provided and a lot of default values are included in the calculation program. If more specific data are found for, e.g., chemical products or dosage, these are very easy to put into the program. This will of course not give the exact answer to what alternative is the best from an environmental point of view, because of the problems with the lack of knowledge of the actual effect on the environment from the use of chemicals and combined with the scatter of data. Still, if it can be accepted that the result is an environmental indication and not an exact answer, the framework could be found to be feasible because it saves a lot of time in establishing different scenarios.

The framework was originally intended as a support for, e.g., architects in a material choice situation. Instead, the interest have been displayed by the floor covering production industry (linoleum, PVC, carpets), where several actors have been helped by the program, while adding their own specific data of recommended maintenance systems. The results of several scenarios have shown clear indications on where improvements could be accomplished in the specific cases.

Finally, it could be pointed out that that the main problem has been to define the production system of the maintenance of floor coverings because of the large variety of alternatives, but the framework has shown that it is possible to handle the impacts from the usage phase in a systematic way. The experiences from the study have led to further research in this area (Paulsen 2001).

2 Methods

2.1 Linoleum and PVC flooring in Sweden

To be able to generalise the maintenance methods, it turned out necessary to only regard professional cleaning. Thus, the study presented here concerns professional cleaning of linoleum and PVC flooring in the Swedish public and service sector. An inventory of the floor covering area in Sweden has been carried out to find out what share of the total floor covering area in Sweden that is encompassed by this study, see Table 1 (Paulsen 1999a). Totally, there is 931 million m² of floor area in Sweden, 526 million m² of which could be regarded as resilient floor coverings. Of the resilient floor coverings, 126 million m² are in the public and service sector, 32 million m² of which are linoleum and 59 million m² are PVC flooring. This means that the PVC and linoleum flooring maintained by professional cleaning only constitute about 10% of the floor area in Sweden, but almost 75% of the resilient floor coverings in the public and service sector. Linoleum and PVC flooring are thereby far the most well-known material in the professional cleaning sector in Sweden.

2.2 Maintenance systems

A critical issue for the study was to see if an agreement could be made on methods and products for maintenance of PVC and linoleum in the professional cleaning sector in Sweden. Several actors were involved in the study. Among them were ISS Sverige AB and Partena Clean, which together have a market share of approximately 40% of the professional cleaning market in Sweden. In addition, three business organisations that participated in the study should be mentioned. These were SG (Swedish Council of Floor Materials and Floor Maintenance), GBR (Swedish National Flooring Trades Association) and IIH (The Swedish Association of Industrial and Institutional Hygiene Products). It was agreed that the maintenance of floor coverings in general could be divided into two main types.

Table 1: Inventory of PVC and Linoleum in Sweden, maintained with professional methods

Type of floor covering	Square metres of floor covering applied in Sweden (in mill. m²)		
	Public and service sector	Residential sector	Total
Resilient floor coverings – Vinyl – Linoleum – Others	126 59 32 35	400	526
Hard floor coverings			405
Total			**931**

The first type of maintenance was designated frequent maintenance and should be regarded as the daily or weekly cleaning process. The second type of maintenance was designated periodical maintenance, which aims to build up and maintain an easily cleaned surface.

However, not all the frequent maintenance concepts are compatible with the periodical maintenance concepts. If a wax system is used for the periodical maintenance, a wax-based cleaning method is required for the frequent maintenance. In the Swedish professional cleaning sector, thereby 36 different maintenance systems could finally be defined, consisting of 6 wax-based systems, and 30 non-wax systems (polish, all-purpose cleaners, oil emulsion, and micro-fibre cloth (see Table 4).

For each of the cleaning methods, an estimation of the resource use for the maintenance of one square metre of floor covering was undertaken (for one occasion of cleaning, which was multiplied by the number of occasions per year, yielding the resource use per square metre and year). Data were collected in terms of energy use, amounts of chemicals, machinery, mops, pads and water. The data are based on agreed averages in the cleaning sector. No efforts have been made in this stage to estimate the spread of data . Indeed, this is an important issue, but in this stage of the study the amount of data was already very large.

The 36 maintenance systems can be used in different scenarios to quantify and compare the environmental loads for different choices of floor coverings and alternatives. However, additional information is also needed. The frequency of the periodical and frequent maintenance for each maintenance system has to be estimated. Also the service life of the floor covering has to be estimated. These estimations cannot be done only based on the knowledge of the type of floor covering and maintenance system. It was agreed to treat these values as more dependent on the actual context in which the floor covering is installed. Therefore the following three parameters have to be estimated to establish a scenario of one or more of the maintenance systems:

1. The frequency of the periodical maintenance (designated P)
2. The frequency of the frequent maintenance (designated F)
3. The expected service life of the floor covering (designated L)

Table 2 shows some possible ranges of the values of P, F and L. The large interval of the service life (L) is due to the fact that the determining factor of the actual service life may be esthetical or economical as well as technical. The service life is discussed in more detail in Paulsen 1999. In Gunther and Langowski (1997), the same problem with the estimation of service life is recognised and estimates are given for an interval between 7 to 40 years for resilient floor coverings in Europe. In addition, the area (A) of the maintained floor covering could be included. Thereby the functional unit becomes 'Maintenance of A square metres of floor covering during L years'.

2.2.1 Periodical maintenance

As of the periodical maintenance, it was agreed that the methods should be limited to three concepts:

1. Wax system
2. Polish system
3. Untreated system

The polish system is a traditional concept, which has existed for a long time in Sweden. The aim is to protect the floor covering with a hard layer of polymers (**Fig. 1**), which has to be replaced several times during the service life of the floor. Polish and polish remover are needed for the system. The polish is applied when the floor covering is installed and then periodically replaced. The polish system is compatible with both linoleum and PVC. Caused by the more porous structure of the linoleum, for this material the amount of chemicals is larger than for PVC, both at application and removal.

The wax system has entered the Swedish market during the latest years, especially for linoleum floorings. The function of the wax is to fill out all irregularities in the floor coverings (see Fig. 1). In doing so, much smaller amounts of chemicals for the surface layer are needed. However, the frequent maintenance has to be carried out with a wax-based cleaning system, which increases the chemical use compared to the frequent maintenance of the polish system. As for polish, the wax is applied when the floor covering is installed and then periodically replaced. The removal may be effected using an 'all-purpose cleaner'. The frequency of this periodical maintenance is similar to that of the polish system. The wax system is compatible with linoleum and PVC, and also here the use of chemicals is larger for linoleum, because of the more porous structure.

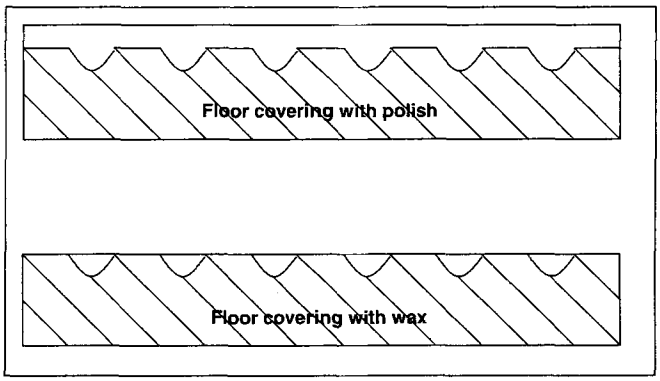

Fig. 1: Enlargement of cross-section for floor coverings to show the principles of polish and wax-systems

Table 2: Symbols and examples of intervals for three application specific parameters

Parameter	Symbol	Frequency (approximately)
Frequent maintenance	F	1–7 times at week
Periodical maintenance	P	0.25–2 times at year
Expected service life	L	5–40 years

Table 3: Distribution of linoleum and PVC floorings in the Swedish professional cleaning sector

Floorings	Polish-system Millions of m^2	Wax-system Millions of m^2	Untreated Millions of m^2
Linoleum flooring	20.8	11.2	0
PVC flooring	40.0	4.5	14.5

The untreated system may be compatible with some types of PVC floorings with polyurethane surface layer. The surface is not treated with any chemicals for periodical maintenance. Table 3 shows how the three systems for periodical maintenance are represented among the 91 million m^2 of PVC and linoleum floor coverings in Sweden, maintained by professional cleaning companies (Paulsen 1999).

2.2.2 Frequent maintenance

The frequent maintenance of linoleum and PVC turned out to be more complex to handle than the periodical maintenance. The cleaning process had to comprise several cleaning agents and methods. However, it was possible to reach a consensus about dominating types of products and methods. The methods could be divided into manual and mechanical methods. For the mechanical methods, a scrubber-drier machine was selected. Different sizes of scrubber-drier machines were inventoried. But calculations based on data from the machine manufacturers revealed that the resource use per square metre of cleaned floor covering was approximately the same, regardless of the size of the machine. The manual methods were divided into three types of mopping; wet mopping, moisture mopping and dry mopping. For the dry mopping, both disposable and recyclable mops were inventoried. For the wet and moisture mopping, only recyclable mops were inventoried. The five cleaning methods could be combined with four cleaning product alternatives: all-purpose cleaner (detergent), wax, oil emulsion and the alternative 'no-cleaning agents (micro-fibre cloth)'. However, not all of the cleaning products and methods were compatible, which resulted in 13 cleaning concepts as shown in Table 4.

2.3 Structure of the study

The study was divided into several stages. The list below presents the main structure of the study:

1. Inventory of floor covering types in Sweden
2. Inventory of methods and amounts of products and resources for maintenance of PVC and linoleum
3. Collection of LCI data of products and resources for the maintenance
4. Provision of an analysis tool, scenario development for maintenance followed by impact assessment of the scenarios with interpretation and conclusions.

The structure could be recognised to be quite similar to the normal structure of an LCA, following the recommendations in ISO 14040-43. The analysis tool was provided to handle the large amount of data and to facilitate the provision of scenarios. Stage 3, the collection of LCI data, proved to be difficult. Especially data of cleaning agents and chemicals were lacking. For the LCI data of PVC and linoleum, a Swedish former study was utilised. In stage 4, several questions of concern to the professional floor covering community (real estate owners, cleaning companies, floor covering producers, cleaning agent producers, etc.) were asked, and the analysis tool was used to develop useful scenarios to support the answers. The scenarios were assessed using impact assessments according to ISO 14042. However, several of the substances found in the LCI were not recognised to have any characterisation factors and thereby difficult to assess quantitatively. It should be mentioned that all energy use is recorded as primary energy.

Collection of LCI data of maintenance products and resources. The LCA data of several products had to be substituted with data of similar products as data were lacking for the actual product. Some processes were totally omitted, because data were lacking and no data of similar processes could be found. Also some transports were omitted after it was demonstrated that they had an insignificant contribution to the impacts.

Floor coverings. A former study on PVC and linoleum flooring for domestic areas was used to collect LCI data of the production of the floor covering (Jönsson 1995). The outcome of this study is re-used here The maintenance in this former study was omitted with the argument that cleaning and maintenance in domestic areas are unpredictable and not correlated to the type of floor covering. The inventory includes data of the production of the floor coverings. This

Table 4: 13 cleaning concepts used professionally in Sweden

Cleaning method	Cleaning Product			
	All-purpose cleaner	Wax	Oil-emulgation	Micro fibre cloth
Scrubber-drier machine				
Scouring	X	X	X	
Recyclable mops				
Wet mopping	X	X		X
Moisture mopping	X	X		X
Dry mopping			X	X
Disposable mops				
Dry mopping			X	X

data were normalised to be valid for the public sector and office environments, which requires a thicker covering. The waste treatment was omitted.

Machinery. The type of scrubber-drier machines for the frequent maintenance is normally chosen in relation to the size of the floor covering. Two different machines were chosen to be representative to the professional cleaning sector in Sweden, a smaller one for areas of 400–1200 m^2 and a larger one for areas of 2000–10,000 m^2. It turned out that the use of electricity, water and cleaning agents was approximately the same per square metre floor covering for both machines. However, the production of the machines was also inventoried to find out if that had any significant influence on the total impacts during the life cycle of the floor coverings. The production of a washing machine and a polishing machine was also inventoried. For none of the four machines, production data could be provided by the producers, and hence the inventories were limited to deal only with the materials in the machines.

Chemicals. A lot of different products are available on the cleaning market, but it was agreed on that data of an 'average product' could be provided by the IIH representing the actual four main products of the maintenance systems. A list of components in the products was set up and inventoried. Also the production process, packaging and transports of the products were inventoried. It turned out to be difficult to find LCI data of several of the components in the products, in which cases data of similar products were employed.

Mops and pads. LCI data of a disposable mop were found in a former study (Ragnsells 1994). As of the recyclable mops, as no data from the producer were found, instead data of the production of the disposable mop were used, normalised by mass. Moreover, pads for the scrubber-drier machines and for the polishing machines were inventoried. No production data were found, so also here the production data of the disposable mop were used (normalised by mass). The packaging and transports of the disposable mops were included in the analysis. For the recyclable mop, transport to and from the laundry was included

Scenario making. To establish scenarios, a tool was developed based on several spreadsheets linked to each other. The program only needs the input of five parameters to create the actual functional unit, comprising several subunits based on the inventory of the maintenance of one square metre of floor covering for one occasion of maintenance. The five input parameters are given in Table 5.

For all of the scenarios, the result was expressed in different effect categories according to (Hauschild & Wenzel 1998). After the inventory and collection of LCI data of the chemicals, it was realised that there was a serious lack of characterisation factors for almost all of the chemicals. In this situation, a dialogue was held with 'Stockholm Vatten', a Swedish company for wastewater treatment in Stockholm. It was concluded that an estimation of potential impacts was difficult to carry out because of the non-linear relationship between load and effect, and the influence of other substances than from maintenance of floor coverings. However, it was suggested that the dry mass of the chemicals could be used as an indicator.

3 Results and Discussion

Because of the described structure of the inventory, no conclusions could be drawn solely from the inventory of the methods and products. For all possible scenarios of the 36 maintenance methods, a choice of maintenance frequencies for periodical and frequent maintenance and an estimation of service life had to be done. During the study, several questions of concern to the cleaning industry turned up. The tool was used to process several relevant scenarios to analyse these issues. The three most interesting questions put by the cleaning sector were as follows:

1. Is the maintenance stage significant compared to the production of floor coverings?
2. Is polish or wax systems to prefer from an environmental point of view?
3. Can the choice of floor covering significantly influence the usage phase?

Issue 1: Maintenance compared to production of floor coverings. The question to answer here is whether the impacts from the usage phase (maintenance) of the floor coverings are significant compared to the impacts from the production of the floor coverings. Using '*energy use*' as a parameter for the comparison between the floor production and maintenance, about 1300 different scenarios were considered. The results revealed that the impacts from the maintenance in 225 cases (17%) exceeded the impacts from the floor production phase and thus constitute a quite significant part of the total impacts of the life cycle. Here it should be mentioned that in the 216 cases where the service life was set to 20 years, the water heating was included and the cleaning frequency was at least twice a week, the impacts from maintenance exceeded the impacts from production in 44% of the cases.

Table 5: Five input parameters to the calculation program

Parameter	Unit	Example
Type of maintenance system	Number (one of 36)	3
Expected service life	Years	20
Frequency for periodical maintenance	Times per year	1
Frequency for frequent maintenance	Times per week	4
Area of floor covering	m^2	1000

Table 6: Energy use for 1000m² floor coverings during 20 years, two scenarios

Parameter	(A) PVC-Wax wet-mopping with wax		(B) Linoleum-Polish scrubber drier machine with All-purpose cleaner	
	Energy (MJ)	Share (%)	Energy (MJ)	Share (%)
Frequent maintenance	**254 960**	**58.0**	**62 200**	**17.2**
Operation of scrubber-drier machine	–		31 200	8.6
All-purpose cleaner	–		10 300	2.9
Pads	–		1 700	0.5
Hot water	58 700	13.3	19 100	5.3
Wax-based cleaning agent	151 400	34.4	–	
Production of recyclable mop	15 600	3.5	–	
Energy for washing machine	27 300	6.2	–	
Washing detergent	1 900	0.4	–	
Periodical Maintenance	**13 800**	**3.1**	**129 900**	**36.0**
Polish-remover	–		33 000	9.1
Polish	–		85 200	23.5
Operation of machines	5 000	1.1	9 900	2.7
Wax	8 100	1.8	–	
All-purpose cleaner	100	0.0	–	
Pads	600	0.1	1 900	0.5
Production of machines	**2 700**	**0.6**	**9 100**	**2.5**
Production of floor coverings	**168 300**	**38.2**	**160 600**	**44.3**
Sum	**439 800**	**100.0**	**364 300**	**100.0**

In Table 6 some figures from two of the scenarios is recorded to show the magnitude of impacts and the respective shares from production and maintenance The two scenarios are chosen, because the parameter values (frequency of cleaning and periodical maintenance, service life and maintenance systems) are quite representative to normal maintenance. Energy use is used as an indicator of impacts. The two scenarios are based on 1000 m² of floor covering having an estimated service life of 20 years, periodical maintenance once a year and cleaning three times a week. In scenario A, the wet-mopping method with wax-based cleaning agent is used on a wax-treated PVC floor. In scenario B, a scrubber-drier machine is used on a polish-treated linoleum floor.

As can be seen, the energy use in the usage phase is larger than the production energy of the floor coverings in both scenarios. However, there is a noticeable difference between the two scenarios. For the polish-based system the periodical maintenance is dominating regarding the energy use and the maintenance system is thereby sensitive to the frequency of the periodical maintenance. For the wax-based system, the situation is the opposite and the maintenance system is very sensitive to how often the floor is cleaned. For both scenarios, the dominating factor is the energy use associated with the extraction and production of chemicals (wax, polish, etc.). In Table 7, the use of some resources is recorded.

Noticeable is that the mass of dry substance from the use of chemicals during the usage phase are about 1/3–2/3 of the mass of the floor covering.

Issue 2: polish systems compared to wax systems. As can be seen in Table 6 and Fig. 1, the impacts from polish and wax

Table 7: Some inventory data for 1000m² floor coverings during 20 years, two scenarios

Parameter	Unit	(A) PVC-Wax wet-mopping with wax	(B) Linoleum-Polish scrubber drier machine with All-purpose cleaner
		Amounts	Amounts
Water	litre	820 114	280 800
Chemicals (dry-substance)	kg	1 859	1 369
Chemicals	litre	6 626	5 273
Packaging	kg	451	359
Pads	kg	5	31
Floor coverings incl. Spillage	kg	2 778	4 089

Table 8: Comparison of production of floors and periodical maintenance for polish-based systems

Parameter	Energy use MJ/m^2	Weight of Chemicals/floor kg/m^2
Periodical maintenance of linoleum	131	4.6
Periodical maintenance of PVC	73	2.6
Difference in periodical maintenance	**58**	**2.0**
Production of linoleum	160	4.1
Production of PVC	168	2.8
Difference in Production	**8**	**1.3**

systems are difficult to compare due to the fact that the magnitude of the impacts are related to different parts of the maintenance. Wax systems require more resources for the cleaning than polish systems, but less resources for the periodical maintenance. In this connection, an important parameter is the relation between the frequent cleaning (F) and the periodical maintenance (P). Scenarios were made for 54 different cases, where wax systems came out better than polish systems in 33 (61%) of the cases. However, the results are sensitive to the chosen cleaning method. In all cases of moisture mopping, the wax system turned out to be the best, but for the wet-mopping method the polish system proved better (13 out of 18). Assuming the use of a combi-machine, the wax system was preferable in 10 out of 18 cases. It should also be mentioned that the overall best system turned out to be the moisture-mopping system with wax. The disadvantage of the wet-mopping systems and combi-machine systems is the relative high dosage of cleaning agents per square metre.

Issue 3: How the choice of floor covering influences the impacts from maintenance. The question to answer here is whether the specific choice of floor covering influences the impacts from the maintenance in a significant way. Assuming that the floor covering has to be maintained with the same system and intervals regardless of the type of floor covering, the impacts from the frequent maintenance will be the same. The difference in impacts in the usage phase will then solely be dependent on the periodical maintenance.

For wax-based systems, the impacts from the periodical maintenance are relatively small. Therefore, the difference in impacts between linoleum and PVC is also relatively small for the periodical maintenance, compared to the differences for the production of the floor coverings. However, for polish-based systems, the difference may be significant. In Table 8, a scenario is shown for polish-treated linoleum and PVC. A service life of 20 years is assumed and a periodical maintenance with polish once every year. Because of the differences in the porous structure of linoleum and PVC, the linoleum requires a larger quantity of polish compared to PVC to obtain the same surface properties. As can be seen in Table 8, the differences between the systems for periodical maintenance are very significant compared to the production of the floor coverings. Consequently, it can also be concluded that the choice of floor covering (PVC or linoleum) will significantly influence the impacts of the usage phase if a polish-based system is chosen and if the service life is expected to be 15–25 years.

4 Conclusions and Perspective

When performing an LCA for one or several products, there may be a large variety in alternatives in modelling the system. It is stated (ISO 1998) that the choice of elements of the physical system to be modelled is dependent on the definition of the goal and scope of the study. One consequence is that input and output that will not significantly change the overall conclusions should not be estimated. However, it is also stated that any decision to omit life cycle stages, processes or inputs/outputs shall be clearly stated and justified. Hence, it is very important to state the reason for an omission of the usage phase, whether it is due to insignificance or due to lack of data or models.

4.1 Provision of a framework

One of the main goals of the study presented in this article (based on Paulsen 1999) was to develop the LCA methodology for handling the usage phase of floor coverings and building products in general. Two of the key issues were to analyse the possibility to estimate the type of products of the methods of maintenance of floor coverings and to quantify the resource use. Several of the assumptions made in the study could of course be refined and discussed, and a variation analysis should be made for several of the input data. However, a framework has been provided as a base for further development. Possibly, the data could be improved and supplied with data of other products and materials. Even other types of floor coverings may be considered. The focus has primarily been on energy use and emission of chemicals recorded as dry substance. A development of a method for quantitative assessment of the actual chemicals is desirable.

Challenges to the inventory in this project have been the great variety of cleaning equipment and machinery together with the lack of LCI data of these. However, with the support from several business organisations it has been possible to reach consensus on a limited number of maintenance methods and so-called 'average products', which, of course, are not representative for all cleaning agents and chemicals, but comprise a valuable base as reference products in the

framework. It makes it possible to explore the consequences if other products are used.

In this study, chemicals were assessed as 'the amount of dry substance', which can be seen as a preliminary category indicator for the ecotoxicological impacts until more appropriate indicators have been developed. Due to lack of LCI-data of the cleaning equipment, some uncertainties to estimate the amount of resource use of each maintenance method still exist. However, the assumed amounts could be seen as reference values, which may be compared with specific systems in a continuous refinement process.

In summary, the inventory and the developed calculation program give the possibility to quantify important parameters and obtain indications of what is important/significant from an environmental point of view concerning the impacts from maintenance of linoleum and PVC. Furthermore, a basis has been provided for comparing and optimising several maintenance systems.

Another important finding was that even though a limited number of maintenance systems could be estimated, the magnitude of the impacts from each system also was depending on the application context and could not be estimated from knowledge of the maintenance system only. The required parameters of the application context are the expected frequency of the maintenance (both frequent and periodical) together with the estimated service life. The consequence is that the scenario development cannot be carried out before the building context is known. A reflection here is that the same structure could be useful for other product groups when impacts from the maintenance are to be inventoried.

4.2 Quantification of environmental impacts from different scenarios

The developed tool made it possible to establish different scenarios and answer several questions. Two of the more important findings were that

1. the impacts from the maintenance of floor coverings have been shown to be an important part of the life cycle. In several cases, the impacts from maintenance could be even higher than the impacts from the production of the floor coverings,
2. the choice of floor covering (PVC or linoleum) influences the magnitude of impacts from the usage phase. For a certain type of maintenance system, the impacts from the periodical maintenance will vary between the floor types. In general, the impacts of the linoleum floor are larger than those of the PVC (for periodical maintenance). However, the best choice of floor coverings depends on the application context.

4.3 Other important aspects

It is important to note that only a limited number of environmental indictors have been inventoried. No considerations have been given to indoor environment or work environment. It should also be noticed that different maintenance methods not always are comparable regarding the cleaning result, it is only assumed that the selected methods are sufficient for their purpose. The economical aspect has not been regarded, which is an important parameter in the choice of a floor covering, but much more important to the choice of maintenance method. The environmental aspect is only one of several parameters in the choice of floor covering and maintenance method. However, it is important that the environmental parameters can be quantified and taken into account as well as an economic parameter.

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